

TEST PLAN

A Comparison of the Panoramic and the AVS-9 Night Vision Goggles During Rotorcraft Hover and Landing

January 17, 2000

Zoltan Szoboszlay
Loran Haworth
Jay Shively

Flight Control and Cockpit Integration Branch
Army/NASA Rotorcraft Division
Ames Research Center
Moffett Field, California

Barry Lakinsmith
Chief, Flight Control and Cockpit Integration Branch
Army/NASA Rotorcraft Division
Ames Research Center, CA

Major David Arterburn
Chief, Flight Projects Office
Aeroflightdynamics Directorate
US Army Aviation and Missile Command

Table of Contents

- 1) Introduction
 - 1.1) Objective of the Test
 - 1.2 Test Goggles
 - 1.3) Test Aircraft and Location
 - 1.4) Customer
 - 1.5) Success Criteria
 - 1.6) Scope of the Test
 - 1.7) Security Classification
- 2) Background
- 3) Previous Research
- 4) Test Matrix
 - 4.1) Tasks
 - 4.1.1) Task #1 Pirouette
 - 4.1.2) Task #2 Bob-Up/Turn/Bob-Down
 - 4.1.3) Task #3 Landing Between Obstacles
 - 4.2) Visual Conditions
 - 4.3) Sample Pilot Population Size
- 5) Measures
 - 5.1) Objective Measures
 - 5.1.1) Aircraft Position
 - 5.1.2) Head Motion
 - 5.1.3) Aircraft Heading
 - 5.1.4) Aircraft Altitude
 - 5.2) Subjective Measures
 - 5.2.1) Handling Qualities Rating
 - 5.2.2) Workload Rating
 - 5.2.3) Situational Awareness Probes
- 6) Test Area
- 7) Preparation for Conducting the Test
 - 7.1) Schedule and Resources Required
 - 7.2) Key Personnel
 - 7.3) Characterizing the Night Vision Devices Used
 - 7.4) Preparing the Aircraft
 - 7.5) Visual Targets Required on Ground
 - 7.6) Preparing the Ground Station Facilities
 - 7.7) Systems Checkout and Calibration
- 8) Conduct of the Test
 - 8.1) Before First Flight for Each Evaluation Pilot
 - 8.1.1) In-briefing
 - 8.1.2) USAF Tri-Bar Resolution Test
 - 8.2) Before Each Flight
 - 8.2.1) Preflight Briefing
 - 8.2.2) Preparation of Ground Equipment
 - 8.2.3) Aircraft Preflight

- 8.3) Flight
 - 8.3.1) Aircraft Configuration
 - 8.3.2) DGPS Position Validation
 - 8.3.3) NVG adjustment
 - 8.3.4) Head Tracker Calibration
 - 8.3.5) Data Collection
 - 8.3.6) Pilot Oral Comments
- 8.4) Post Flight
 - 8.4.1) Post Flight Briefing
 - 8.4.2) Pilot Written Comments
 - 8.4.3) Verification of data collection
- 8.5) After Last Flight of Each Evaluation Pilot
 - 8.5.1) Out Briefing
- 9) Post Test
 - 9.1) Photo and Video Documentation
 - 9.2) Data Analysis
 - 9.3) Archiving of Raw and Processed Data
 - 9.4) Test Reports
- 10) Risk Identification, Mitigation, and Assessment
 - 10.1) Overall Risk Assessment
 - 10.2) Identification, Mitigation, and Assessment of Each Risk
 - 10.2.1) Collision with Obstacles
 - 10.2.2) Collision with Ground
 - 10.2.3) Operation Inside the “Avoid” Region of the Height Velocity Chart
 - 10.2.4) Failure of the Night Vision Device
 - 10.2.5) Bright Lights in the Maneuver Area
 - 10.2.6) Head Tracker Cord Attachment
 - 10.2.7) Failure of Experimental Systems
 - 10.2.8) Loose Objects in the Cockpit
 - 10.2.9) Standing Water and Mud in Test Area
- 11) Safety Checklist
 - 11.1) Verify Once Before Tests Begin
 - 11.1.1) Safety Review
 - 11.1.2) PNVG-2 Operation Training
 - 11.1.3) Evaluation Pilot Head Tracker Cord Detachment
 - 11.1.4) Cockpit GPS Navigation Inoperative
 - 11.1.5) Briefing to Airfield Management and Base Operations
 - 11.1.6) Verification of No Lighting Hazards
 - 11.1.7) Team Briefing
 - 11.1.8) Submitting Forms for Human Subject Use
 - 11.1.9) Aircraft Weight and Balance
 - 11.1.10) Maintenance and inspection Requirements of the Goggles
 - 11.1.11) Electro-Magnetic Compatibility Check
 - 11.1.12) NVG Storage in Cockpit

11.2) Verify Before Each Flight

- 11.2.1) Research Pilot Qualifications and Training
- 11.2.2) Evaluation Pilot Qualifications and Training
- 11.2.3) Ground Crew Requirements
- 11.2.4) Aircrew Coordination
- 11.2.5) Briefings
- 11.2.6) Other Pilot And Non-Pilot Evaluation of the PNVGs
- 11.2.7) Displays used by the Research Pilot
- 11.2.8) Covering the Evaluation Pilot's Indicators
- 11.2.9) Aircraft Maneuver Constraints
- 11.2.10) Wind Constraints
- 11.2.11) Weather Constraints
- 11.2.12) Minimum/Maximum Fuel Constraints
- 11.2.13) Crash/Rescue Requirements
- 11.2.14) Control Tower Requirements
- 11.2.15) Required Radio Contacts
- 11.2.16) Pilot Survey of the Test Area
- 11.2.17) Ambient Lighting Constraints
- 11.2.18) Operation of the Laser Tracker
- 11.2.19) Visual Markers
- 11.2.20) Release Forms
- 11.2.21) Crew Rest
- 11.2.22) Chase Aircraft

12) References

1) Introduction

1.1) Objective of the Test

The objective of this test is to determine if there are differences in performance of the pilot, in the workload of the pilot, or in the situational awareness of the pilot between flying a rotorcraft with a prototype Panoramic Night Vision Goggle (PNVG-2), and flying the same rotorcraft with the currently fielded AVS-9 goggle. Two hover and one landing task will be flown for this test.

1.2 Test Goggles

The two goggles to be flown are shown in figures 1.1a and 1.1b. The most striking difference between these goggles is the amount of field-of-view (FOV). As shown in figure 1.1c, the PNVG-2 has 100 degrees of horizontal FOV in comparison to the 40 degrees horizontal FOV of the AVS-9. The PNVG-2 has slightly worse resolution and heavier weight than the PNVG-2 goggles. Note that the military uses mostly AVS-6 goggles which have the same FOV as the AVS-9 goggles. However, the AVS-9 goggles have slightly better resolution and adjustment mechanisms.



Figure 1.1a. PNVG-2 goggle.



Figure 1.1b. AN/AVS-6, -9 goggle.

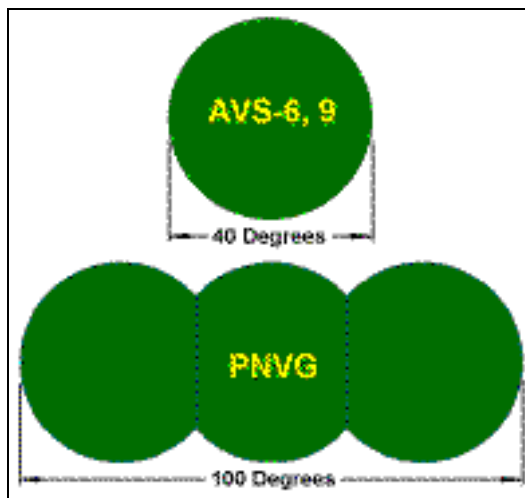


Figure 1.1c. Fields-of-View of the AVS-6, AVS-9, and PNVG-2 goggles.

1.3) Test Aircraft and Location

Two hover maneuvers and a landing maneuver will be flown at Moffett Federal Airfield, California, in a U.S. Army NAH-1S (Cobra) helicopter S/N 70-15979. This aircraft is shown in figure 1.2a



Figure 1.2a. NAH-1S Test Aircraft

1.4) Customer

The primary customers for the data generated in this test is the Air Force Research Laboratory (AFRL), and the Army/NASA Rotorcraft Division at Ames Research Center. Points of contact at the AFRL: Jeffrey Craig 937-255-7592, and Eric Geiselman 937-255-3951. Points of contact for the Army/NASA Rotorcraft Division are Zoltan Szoboszlay 650-604-5164 and Loran Haworth 650-604-6944.

1.5) Success Criteria

There is no bias in this test that the PNVG-2s are superior, the same, or worse than the AVS-9 NVGs. This test will be successful if enough data is collected to show that there are or are not differences in the performance, workload, or situational awareness of pilots using PNVG-2s as opposed to AVS-9 goggles, for the particular sample hover tasks flown. This test will be unsuccessful if not enough data is collected to determine whether there are or are not differences.

1.6) Scope of the Test

This test is an initial evaluation, and is not intended to cover the range of operational maneuvers, range of visual conditions (rain, fog, full moon, no moon, etc.), and range of terrain expected in an operational environment.

1.7) Security Classification

All documentation and data generated from this test will be unclassified. All documents and data from this test will have unlimited distribution.

2) Background

Night vision goggles amplify light levels seen by the pilot from levels that are too low to be usable by the pilot to light levels that are usable in most cases. However, the image seen through the goggles is still reduced from normal, unaided vision in FOV, resolution, contrast, color, and the dynamic range of usable ambient light levels. Furthermore, the goggles prevent the pilot from being able to focus the image through the goggles for both out the window and in the cockpit. Improperly aligned and focused goggles may also cause eye fatigue.

The United States Army Aeromedical Research Laboratory report of helicopter accidents between 1987-1992 showed a drastic increase in the number of accidents when pilots flew NVGs as compared to daylight flight, as shown in figure 2a¹. It has been suspected by this test organization, but not proven, that one contributing factor in many accidents was the reduction in the FOV of the pilot in comparison to normal, unrestricted FOV. The PNVG-2, with its greater FOV, has the potential to increase pilot performance, decrease workload, and improve the situational awareness of pilots.

US Army spatial disorientation accident rates per 100,000 flying hours:

1.5 Day

5.5 Night

17.8 Night with 40° FOV night vision goggles
--

Figure 2a. Relevant accident data from US Army Aeromedical Research Laboratory Report No. 95-25¹.

3) Previous Research

The PNVGs were flown aboard OH-58, UH-60 and CH-47 US Army rotorcraft at Ft. Rucker, Alabama in Nov. and Dec. 1999. These flights were a cooperative evaluation by the US Army Aeromedical Research Laboratory and the US Army Night Vision and Electronic Sensors Directorate. Pilot questionnaires were filled out by the evaluation pilots. The results of this evaluation have not yet been published.

An early prototype PNVG goggle was flown aboard an AH-1 helicopter at Ft. Carson, Colorado in 1997. This test was conducted by the US Army Night Vision and Electronic Sensors Directorate. The aircraft was flown low level, at night, in mountain terrain. Subjective questionnaires were provided by the evaluation pilots. Favorable comments were obtained for the PNVG goggles. (No references available)

The PNVG-1s are being flown aboard two USAF F-15 aircraft. Subjective questionnaires were provided by the evaluation pilots, and the SA-SWORD situational awareness methods applied. This test is still on-going. The results of this evaluation have not yet been published. However, favorable ratings were already obtained for the PNVGs.

A flight test was performed in cooperation with the Army Aeroflightdynamics Directorate (AFDD), NASA, and the UK Defence Evaluation and Research Agency^{2,3}. This test measured pilot performance and workload while the pilot flew precise, low level maneuvers with varying fields-of-view. The NAH-1S Cobra aircraft used in the United States, and a Mk 7 Lynx was used in the United Kingdom. Fields-of-view varied in random order among values of unrestricted, 20° (NAH-1S only), 40°, 60°, 80°, and 100°. This test demonstrated that performance improved with FOV measurably up to a range between 60° – 80° for most of the maneuvers flown. This test also showed that head movement varied with pilot FOV.

Monterey Technologies Inc. is currently conducting a series of simulations with a helmet mounted display that has two center visual channels with 100% overlap, and two peripheral channels with no overlap. This arrangement is therefore similar to the PNVGs. Imagery and symbology (computer graphics) is displayed in the center channels. The peripheral channels show symbology only. Monterey Technologies Inc. is attempting to demonstrate the impact of visual flow fields in the peripheral areas of FOV on the pilot's perception of self-motion and self-attitude. This work is being done as a Small Business Innovative Research (SBIR) contract for the AFDD. Particularly relevant to this flight test is the literature search detailing the theory of ambient and focal vision. The Phase I final report describes the implications of increased FOV on the perception of self-motion⁴.

A report by Kaiser Electronics describes the four methods of overcoming FOV and resolution limitations of traditional optics⁵. Kaiser has also developed a helmet mounted display similar to the PNVGs that use four visual channels. Similar to the PNVGs, the ProView100 has two center channels that are 100% overlapped. Unlike the PNVGs, there is also some overlap with the peripheral channels to provide a seam-less display.

4) Test Matrix

This section details the test matrix. Figures 4a through 4d show a summary chart of the overall test matrix, including training flights. The matrix is the same for pilots #1 and #3. Likewise the matrix is the same for pilots #2 and #4. Only four pilots are planned due to time and budget constraints. Twenty eight hours of flight time are required for the four evaluation pilots, 25 hours are required for research pilot training, and up to 5 hours of demonstration flights may be provided to non-evaluation pilots and non-pilots.

During night data flights, the evaluation pilot must exchange the two types of goggles on three occasions as shown in the rightmost column of the test matrix. The goggles will be exchanged while the aircraft is on the ground, immediately following the evaluation pilot ratings. The goggle not being used is stored in a specially constructed mount in the cockpit.

The test matrix is structured to reduce learning effects. Each evaluation pilot will have one day training flight before data are collected during the day. Likewise, the pilot will have one night training flight before data are collected at night. Additionally, the day flights are performed before the night flights in order to have the pilots better practiced for the more important night data flights. In addition, each evaluation pilot must have the qualifications and training hours detailed in section 11 of this test plan.

Pilot	First Flight <u>Training</u> Day 2.0 hrs	Second Flight <u>Data</u> Day 1.0 hr	Third Flight <u>Training</u> Night 2.0 hrs	Fourth Flight <u>Data</u> Night 2.0 hrs
Pilot #1	DAY-Task 1 Repeat as req'd	DAY-Task 1 practice DAY-Task 1 data-a DAY-Task 1 data-b <u>Provide ratings</u>	PNVG-Task 1 Repeat as req'd	PNVG-Task 1 practice PNVG-Task 1 data-a PNVG-Task 1 data-b <u>Provide ratings</u>
			PNVG-Task 2 Repeat as req'd	NVG-Task 1 practice NVG-Task 1 data-a NVG-Task 1 data-b <u>Provide ratings</u>
	DAY-Task 2 Repeat as req'd	DAY-Task 2 practice DAY-Task 2 data-a DAY-Task 2 data-b <u>Provide ratings</u>	PNVG-Task 3 Repeat as req'd	NVG-Task 2 practice NVG-Task 2 data-a NVG-Task 2 data-b <u>Provide ratings</u>
			NVG-Task 1 Repeat as req'd	PNVG-Task 2 practice PNVG-Task 2 data-a PNVG-Task 2 data-b <u>Provide ratings</u>
	DAY-Task 3 Repeat as req'd	DAY-Task 3 practice DAY-Task 3 data-a DAY-Task 3 data-b <u>Provide ratings</u>	NVG-Task 2 Repeat as req'd	PNVG-Task 3 practice PNVG-Task 3 data-a PNVG-Task 3 data-b <u>Provide ratings</u>
			NVG-Task 3 Repeat as req'd	NVG-Task 3 practice NVG-Task 3 data-a NVG-Task 3 data-b <u>Provide ratings</u>

Figure 4a. Order of training and data collection flights for pilot #1.

Pilot	First Flight <u>Training</u> Day 2.0 hrs	Second Flight <u>Data</u> Day 1.0 hr	Third Flight <u>Training</u> Night 2.0 hrs	Fourth Flight <u>Data</u> Night 2.0 hrs
Pilot #2	DAY-Task 1 Repeat as req'd	DAY-Task 1 practice DAY-Task 1 data-a DAY-Task 1 data-b <u>Provide ratings</u>	NVG-Task 1 Repeat as req'd	NVG-Task 1 practice NVG-Task 1 data-a NVG-Task 1 data-b <u>Provide ratings</u>
	DAY-Task 2 Repeat as req'd	DAY-Task 2 practice DAY-Task 2 data-a DAY-Task 2 data-b <u>Provide ratings</u>	NVG-Task 2 Repeat as req'd	PNVG-Task 1 practice PNVG-Task 1 data-a PNVG-Task 1 data-b <u>Provide ratings</u>
	DAY-Task 3 Repeat as req'd	DAY-Task 3 practice DAY-Task 3 data-a DAY-Task 3 data-b <u>Provide ratings</u>	NVG-Task 3 Repeat as req'd	PNVG-Task 2 practice PNVG-Task 2 data-a PNVG-Task 2 data-b <u>Provide ratings</u>
			PNVG-Task 1 Repeat as req'd	NVG-Task 2 practice NVG-Task 2 data-a NVG-Task 2 data-b <u>Provide ratings</u>
			PNVG-Task 2 Repeat as req'd	NVG-Task 3 practice NVG-Task 3 data-a NVG-Task 3 data-b <u>Provide ratings</u>
			PNVG-Task 3 Repeat as req'd	PNVG-Task 3 practice PNVG-Task 3 data-a PNVG-Task 3 data-b <u>Provide ratings</u>

Figure 4b. Order of training and data collection flights for pilot #2.

Pilot	First Flight <u>Training</u> Day 2.0 hrs	Second Flight <u>Data</u> Day 1.0 hr	Third Flight <u>Training</u> Night 2.0 hrs	Fourth Flight <u>Data</u> Night 2.0 hrs
Pilot #3	DAY-Task 1 Repeat as req'd	DAY-Task 1 practice DAY-Task 1 data-a DAY-Task 1 data-b <u>Provide ratings</u>	PNVG-Task 1 Repeat as req'd	PNVG-Task 1 practice PNVG-Task 1 data-a PNVG-Task 1 data-b <u>Provide ratings</u>
	DAY-Task 2 Repeat as req'd	DAY-Task 2 practice DAY-Task 2 data-a DAY-Task 2 data-b <u>Provide ratings</u>	PNVG-Task 2 Repeat as req'd	NVG-Task 1 practice NVG-Task 1 data-a NVG-Task 1 data-b <u>Provide ratings</u>
	DAY-Task 3 Repeat as req'd	DAY-Task 3 practice DAY-Task 3 data-a DAY-Task 3 data-b <u>Provide ratings</u>	PNVG-Task 3 Repeat as req'd	NVG-Task 2 practice NVG-Task 2 data-a NVG-Task 2 data-b <u>Provide ratings</u>
			NVG-Task 1 Repeat as req'd	PNVG-Task 2 practice PNVG-Task 2 data-a PNVG-Task 2 data-b <u>Provide ratings</u>
			NVG-Task 2 Repeat as req'd	PNVG-Task 3 practice PNVG-Task 3 data-a PNVG-Task 3 data-b <u>Provide ratings</u>
			NVG-Task 3 Repeat as req'd	NVG-Task 3 practice NVG-Task 3 data-a NVG-Task 3 data-b <u>Provide ratings</u>

Figure 4c. Order of training and data collection flights for pilot #3.

Pilot	First Flight <u>Training</u> Day 2.0 hrs	Second Flight <u>Data</u> Day 1.0 hr	Third Flight <u>Training</u> Night 2.0 hrs	Fourth Flight <u>Data</u> Night 2.0 hrs
Pilot #4	DAY-Task 1 Repeat as req'd	DAY-Task 1 practice DAY-Task 1 data-a DAY-Task 1 data-b <u>Provide ratings</u>	NVG-Task 1 Repeat as req'd	NVG-Task 1 practice NVG-Task 1 data-a NVG-Task 1 data-b <u>Provide ratings</u>
	DAY-Task 2 Repeat as req'd	DAY-Task 2 practice DAY-Task 2 data-a DAY-Task 2 data-b <u>Provide ratings</u>	NVG-Task 2 Repeat as req'd	PNVG-Task 1 practice PNVG-Task 1 data-a PNVG-Task 1 data-b <u>Provide ratings</u>
	DAY-Task 3 Repeat as req'd	DAY-Task 3 practice DAY-Task 3 data-a DAY-Task 3 data-b <u>Provide ratings</u>	NVG-Task 3 Repeat as req'd	PNVG-Task 2 practice PNVG-Task 2 data-a PNVG-Task 2 data-b <u>Provide ratings</u>
			PNVG-Task 1 Repeat as req'd	NVG-Task 2 practice NVG-Task 2 data-a NVG-Task 2 data-b <u>Provide ratings</u>
			PNVG-Task 2 Repeat as req'd	NVG-Task 3 practice NVG-Task 3 data-a NVG-Task 3 data-b <u>Provide ratings</u>
			PNVG-Task 3 Repeat as req'd	PNVG-Task 3 practice PNVG-Task 3 data-a PNVG-Task 3 data-b <u>Provide ratings</u>

Figure 4d. Order of training and data collection flights for pilot #4.

4.1) Tasks

Three low airspeed maneuvering and hovering tasks will be flown by all evaluation pilots. For safety reasons, all tasks will be flown on a flat maneuver area with no obstacles. The maneuver tasks are defined by courses outlined with orange safety cones and paint. These maneuvers were chosen because they showed a strong correlation between performance, head movement, and FOV during previous tests^{2,3}. All maneuvers are flown according to the pilot's body position, as opposed to the aircraft mast position. For all maneuvers, the evaluation pilot's altimeters, attitude indicators, and heading indicators will be covered.

4.1.1) Task #1 Pirouette

For the pirouette maneuver, the evaluation pilot (front cockpit) must fly the aircraft around a 100 foot radius circle, keeping the nose of the aircraft pointed toward the center of the circle. The research pilot (aft cockpit) will set the aircraft at the correct altitude, heading, and longitudinal position before the maneuver begins. The evaluation pilot must maintain altitude, heading, and longitudinal position while flying the aircraft along the perimeter of the entire circle.

The visual cues for this task will be a single, painted white line marking the circumference of the 100 ft radius circle. A single traffic cone will be placed at the center of the circle. Four traffic cone will be placed inside the perimeter of the circle 90 degrees apart. All traffic cones will be illuminated with internal lights optimized for the NVGs.

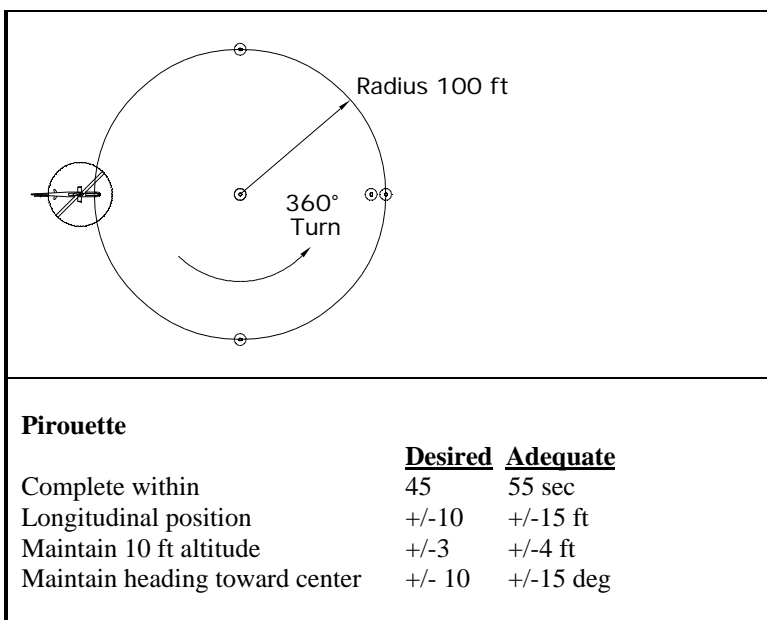


Figure 4.1.1a. Pirouette Task.

4.1.2) Task #2 Bob-Up/Turn/Bob-Down

For this maneuver, the research pilot (aft cockpit) stabilizes the aircraft in a hover at 10 ft altitude, at the desired heading. The evaluation pilot then takes the controls, and continues the hover at 10 ft altitude, maintaining his/her body position over the hover point. The evaluation pilot then ascends to 50 ft altitude, using an outside visual cue for height judgement (such as distant towers). The evaluation pilot then completes a 360 degree turn counterclockwise, stabilizes, and then descends back down to 10 ft altitude. For the entire duration of the task, the evaluation pilot is to maintain his/her body position (as opposed to the main rotor mast position) over the hover point. This maneuver is flown at the center of the pirouette course. The visual markings are the same as the pirouette.

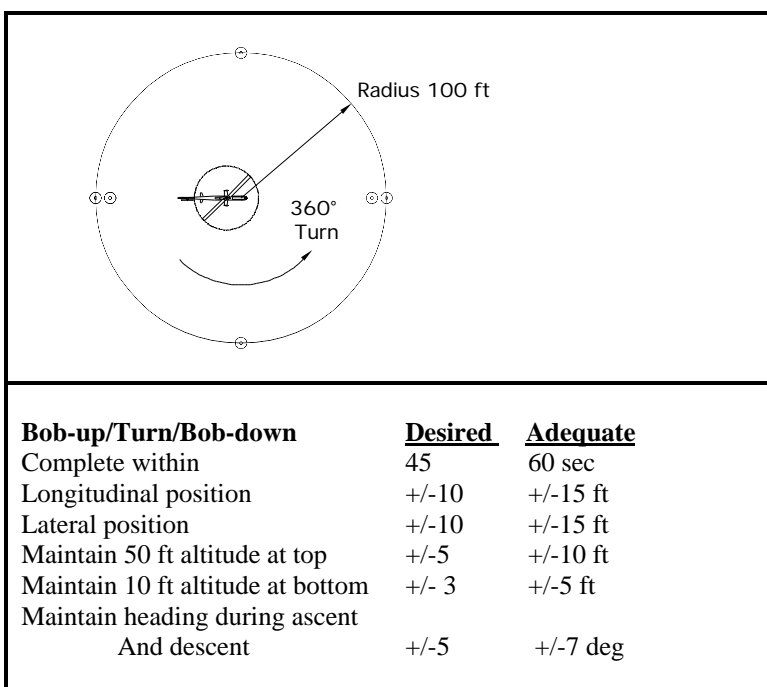
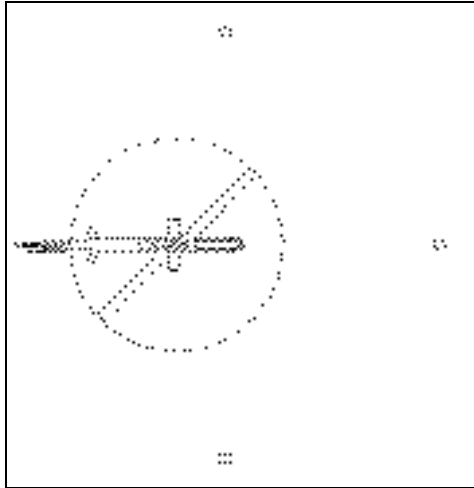


Figure 4.1.2a. Bob-Up Task

4.1.3) Task #3 Landing Between Obstacles

The third task will be a landing between three simulated obstacles. The research pilot (aft cockpit) will set the aircraft in a stable hover at 15 ft altitude (measured with the radar altimeter) and 200 feet from the landing point. The evaluation pilot will then take the controls, move forward, and land the aircraft such that the pilot's body position will be as equidistant from the three visual markers as possible. The evaluation pilot must also maintain a heading toward the forward marker, as shown in figure 4.1.3a. These visual markers are placed 1 rotor diameter around the landing center point.



Landing	<u>Desired</u>	<u>Adequate</u>
Complete within	15	25 sec
Longitudinal position	+/-2	+/-4 ft
Lateral position	+/-2	+/-4 ft
Maintain heading	+/-5	+/-10 deg

Figure 4.1.3a Landing between obstacles.

4.2) Visual Conditions

There are three visual conditions for this test:

- Night with AVS-9 goggles
- Night with PNVG-2 goggles
- Day with unrestricted vision, as a baseline

4.3) Sample Pilot Population Size

The third dimension of the test matrix is the number of pilots performing the test matrix. Initially, four evaluation pilots are planned for this test. However, more pilots may be required if there is excessive scatter in the data. The amount of scatter will be checked at the end of the fourth pilot's data runs.

5) Measures

5.1) Objective Measures

Objective measures are taken directly from calibrated sensors. The data are not modified by human perception. All data are time-stamped with GPS time.

5.1.1) Aircraft Position

The aircraft position in the horizontal plane is measured with a Differential Global Positioning System (DGPS) that will have better than 10 cm accuracy in the horizontal plane and update at 10 Hz. The DGPS antenna will be placed directly over the pilot's nominal head position, so that the plot of the antenna position in the horizontal plane will closely correspond with the path of the pilot's head position.

5.1.2) Head Motion

The angle of the evaluation pilot's helmet is measured in 3 dimensions: azimuth, elevation, and roll. The amount of movement of the pilot's head is a workload measure, as opposed to a performance measure. The head tracker data is recorded at 32 Hz, with approx. 2 degrees of accuracy.

5.1.3) Aircraft Heading

The aircraft heading is measured with a gyro and recorded at 32 Hz.

5.1.4) Aircraft Altitude

Vertical position above the terrain is measured with a radar altimeter. The altitude is measured and recorded at 32 Hz. DGPS may not provide sufficient accuracy in altitude due to the geometry of the position triangulation.

5.2) Subjective Measures

Subjective measures are provided by the evaluation pilot. The data are modified by human perception. Each pilot will provide ratings and supporting and qualifying comments over the radio, to be recorded on the ground.

5.2.1) Handling Qualities Rating

At the end of each condition in the test matrix, the pilot will provide handling qualities ratings (HQR) using the Cooper-Harper Rating Scale.

5.2.2) Workload Rating

At the end of each condition in the test matrix, the pilot will provide workload ratings using the NASA-TLX and SWAT workload scales.

5.2.3) Situational Awareness Probes

At the end of each condition in the test matrix, the pilot will complete the Situational Awareness Probes which are questionnaires. One example situational awareness probe is to ask the pilot what he/she thought the longitudinal and lateral position errors were for the maneuver just flown.

6) Test Area

The maneuvers will be flown at the departure end of runway 32L, as shown in figure 6a. If the ground is sufficiently dry, the test team will use the grass fields in order to eliminate the presence of the orthogonal grid of lines caused by the layout of the concrete blocks. This grid is an undesirable visual cue for this test. The test team will leave the visual markers for this test in the grass fields for the duration of the test if approved by the Moffett Airfield Management Office.

If the soil is soft from rain such that the grass fields are unsuitable for hover and landing, the test team will use the most northern end of the west parallel taxiway for the maneuvers. In this case the Flight Test Director will coordinate with the Moffett Airfield Management Office and Base Operations for the installation and removal of the visual markers.

The Test Director is responsible for obtaining permission from the Airfield Management Office to place the visual markings on the grass and west parallel taxiway. The test director will coordinate through the Chief, FPO or the Airfield Management Office for the issuance of a NOTAM indicating that 32L and the west parallel are closed while day/NVG operations are conducted in the test area.

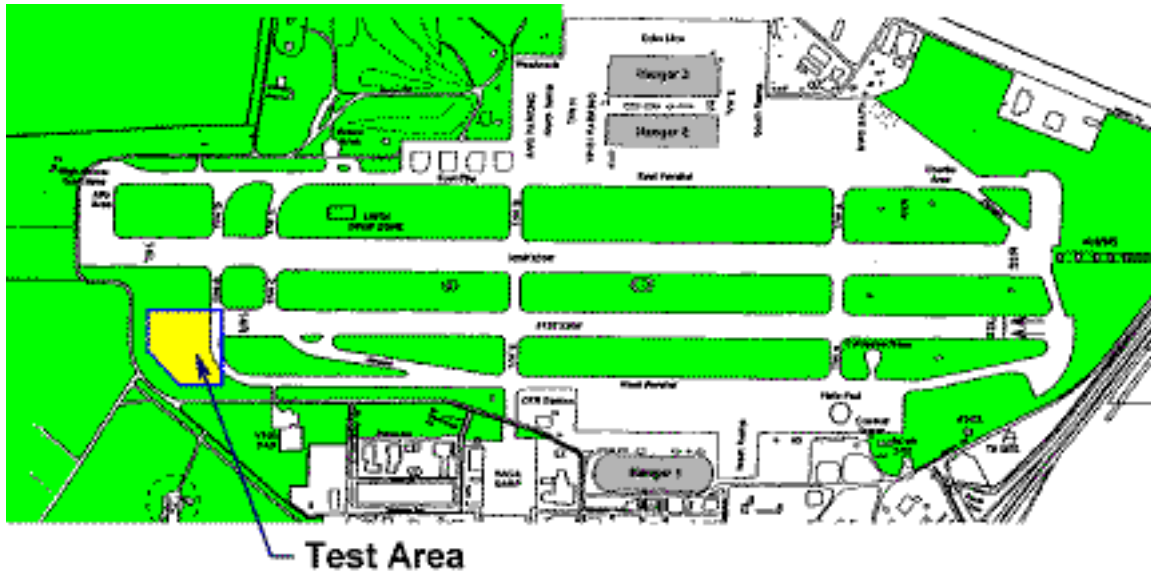


Figure 6a. Test area at Moffett Field.

7) Preparation for Conducting the Test

7.1) Schedule and Resources Required

The schedule and resources required are separate ISO 9000 documents.

7.2) Key Personnel

The Principal Investigator for this test is Zoltan Szoboszlay. Assisting investigators are Loran Haworth, Joe DeMaio, and Jay Shively. The research pilots (aft cockpit) are Loran Haworth and Munro Dearing. Raytheon Aerospace will provide maintenance support, as well as electrical and mechanical fabrication required to instrument the aircraft for this flight test. Zoltan Szoboszlay will be the Project Engineer. Alan Lee and Zoltan Szoboszlay will be the test directors. Alan Lee will provide aerospace engineering support. A safety review will be conducted by the Safety of Flight Review Board at Ames Research Center. Reference section 11 for specific training requirements for personnel evolved in this test.

7.3) Characterizing the Night Vision Devices Used

The physical characteristics of the PNVG-2 have been documented by the Air Force Research Lab, and the manufacturer Night Vision Corporation (Lincolnwood IL)⁶. The physical characteristics of the AN/AVS-9 night vision goggle have been documented by the Air Force and the manufacturer ITT.

However, the image seen by each evaluation pilot is also a function of the ambient illumination, proper focus of the goggles, and the visual acuity of the pilot with the particular corrective eyewear used by that pilot. Therefore, each evaluation pilot will perform a resolution test of each tube of both goggles, as described in the section 9 of this test plan.

7.4) Preparing the Aircraft

The test aircraft must be modified as shown in figure 6.3a, and detailed below.

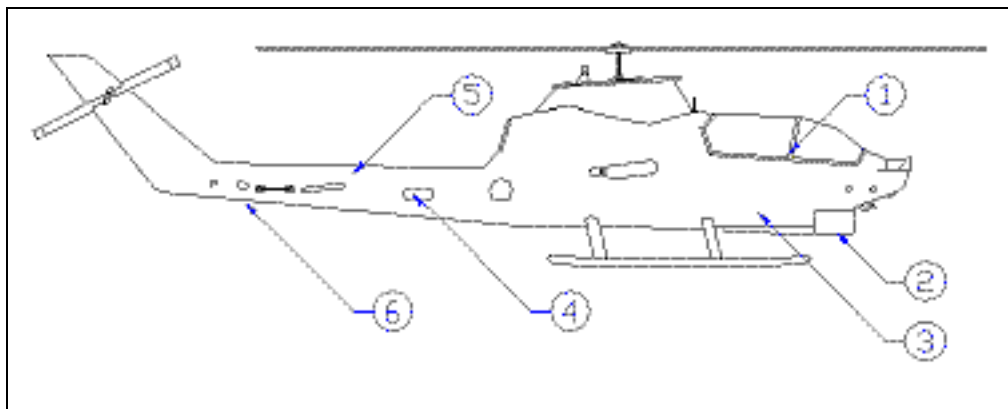


Figure 7.4a. Aircraft modifications required for this test.

- 1.) Reinstall the head tracker transmitter on aft cockpit glare shield.
Install the head tracker sensor on evaluation pilot's helmet using Velcro or tape.

Disconnect cockpit GPS navigation unit.

Replace current GPS antenna (used for cockpit GPS unit) on canopy with new antenna.

Cover the front cockpit instruments for altitude, attitude, and heading.

Fabricate and install a device for securing both types of night vision goggles.

2.) Install head tracker electronics unit in the ballast turret

Install the GPS receiver in the ballast turret.

Install the GPS uplink radio modem and antenna.

3.) Reinstall the 12/9/7.5 volt power supply in the ammo bay.

Redirect the heading gyro signal and radar altimeter signal from the Pilot Night Vision System to the data acquisition system. Install a syncro-DC converter in the ammo bay.

4.) Reinstall the data acquisition computer and disk drive in the tail boom.

5.) Reinstall the 60 Hz power supply in the tail boom.

6.) Install a data acquisition uplink/downlink radio modem and antenna.

7.) Disconnect the white anticollision light, and connect the red anticollision light.

8.) Install the NVG filter on the search light.

Hardware and software configuration control will be implemented according to the established procedures of the Flight Control and Cockpit Integration Branch, and the Flight Projects Office.

7.5) Visual Targets Required on Ground

The test director will be responsible for the placement of visual targets required for the maneuvers. These targets are a combination of orange traffic cones and paint. The cones will be weighted down with metal chain to prevent the rotor down wash from moving the cones. At night, lights will be placed in the traffic cones. These lights will be self-contained, either battery powered or chemical powered (light sticks), and will be optimized for visibility through the NVGs. The test director will coordinate installation and removal of these visual markers with the Airfield Management Office and Base Operations prior to conducting any day or NVG operations.

7.6) Preparing the Ground Station Facilities

A ground vehicle will be set up as a differential GPS ground base station. This base station consists of a GPS receiver, and a radio transmitter. The transmitter will be a 902-928 MHz spread spectrum transceiver that is FCC part 15 compliant. Therefore no license is required. . This vehicle will be set up as close to the test site as there is electrical power available, in order to maximize radio signal quality.

The ground vehicle will also function as a portable ground station. This station consists of a radio modem and a portable computer which controls data collection on board the aircraft. The radio modem is also a 902-928 MHz spread spectrum transceiver that is FCC part 15 compliant. The two transceivers should not interfere with each other since they use different digital modulation codes. System tests will be conducted to confirm that the two radios do not interfere with each other.

7.7) Systems Checkout and Calibration

A checkout will occur before the test begins of all the equipment and facilities used for the test to insure proper operation of that equipment and facilities. The test team will evaluate the DGPS system on the ground for accuracy and drift before the tests begin. The calibration point for the DGPS will be the center of the pirouette, with the DGPS axis aligned to magnetic north. In addition, the analog parameters (heading, radar altitude, pilot stick positions) of the data acquisition system will be calibrated to ensure that data conversion factors are correct. The software version for the data acquisition system and the DGPS receiver will remain fixed for the duration of the test.

8) Conduct of the Test

For each of the four evaluation pilots, the desired schedule will be as follows:

Monday – 2.0 hr. day training flight including the three tasks defined in this plan.

Monday – On ground, perform Air Force Tri Bar resolution test of all NVG tubes.

Tuesday – 1.0 hr. day data flight, in the late afternoon.

Tuesday – 2.0 hr. night training flight including the three tasks defined in this plan.

Wednesday – 2.0 hr. night data flight

Thursday – Backup flight date, aircraft maintenance, or demo flights.

Friday – Backup flight date, aircraft maintenance, or demo flights.

Figure 8a shows the solar and lunar almanac for the time period of this test. Flights on the weeks of the full moon are not desired due to the large illumination levels.

MON	TUE	WED	THUR	FRI
<u>Feb 28</u> 39% moon 18:02 sunset 02:15 moonrise 12:21 moonset	<u>Feb 29</u> 30% moon 18:03 sunset 03:07 moonrise 13:07 moonset	<u>Mar 1</u> 22% moon 18:04 sunset 03:55 moonrise 13:57 moonset	<u>Mar 2</u> 15% moon 18:05 sunset 04:40 moonrise 14:52 moonset	<u>Mar 3</u> 8% moon 18:06 sunset 05:22 moonrise 15:49 moonset
<u>Mar 6</u> 0% moon 18:09 sunset 07:08 moonrise 18:52 moonset	<u>Mar 7</u> 2% moon 18:10 sunset 07:40 moonrise 19:56 moonset	<u>Mar 8</u> 5% moon 18:11 sunset 08:12 moonrise 21:01 moonset	<u>Mar 9</u> 11% moon 18:12 sunset 08:45 moonrise 22:06 moonset	<u>Mar 10</u> 19% moon 18:13 sunset 09:21 moonrise 23:13 moonset
<u>Mar 13</u> 51% moon 18:16 sunset 11:38 moonrise 01:26 moonset	<u>Mar 14</u> 62% moon 18:17 sunset 13:35 moonrise 02:29 moonset	<u>Mar 15</u> 73% moon 18:17 sunset 13:39 moonrise 03:26 moonset	<u>Mar 16</u> 84% moon 18:18 sunset 14:45 moonrise 04:17 moonset	<u>Mar 17</u> 90% moon 18:19 sunset 15:53 moonrise 05:01 moonset
<u>Mar 20</u> 100% moon 18:22 sunset 19:09 moonrise 06:49 moonset	<u>Mar 21</u> 98% moon 18:23 sunset 20:12 moonrise 07:21 moonset	<u>Mar 22</u> 95% moon 18:24 sunset 21:12 moonrise 07:52 moonset	<u>Mar 23</u> 89% moon 18:25 sunset 22:12 moonrise 08:24 moonset	<u>Mar 24</u> 82% moon 18:26 sunset 23:10 moonrise 08:58 moonset
<u>Mar 27</u> 57% moon 18:29 sunset 00:59 moonrise 10:59 moonset	<u>Mar 28</u> 47% moon 18:29 sunset 01:49 moonrise 11:48 moonset	<u>Mar 29</u> 38% moon 18:30 sunset 02:35 moonrise 12:40 moonset	<u>Mar 30</u> 29% moon 18:31 sunset 03:17 moonrise 13:36 moonset	<u>Mar 31</u> 20% moon 18:32 sunset 05:56 moonrise 14:34 moonset
<u>Apr 3</u> 3% moon 18:35 sunset 05:38 moonrise 17:41 moonset	<u>Apr 4</u> 0% moon 18:36 sunset 06:11 moonrise 18:47 moonset	<u>Apr 5</u> 1% moon 18:37 sunset 06:44 moonrise 19:54 moonset	<u>Apr 6</u> 3% moon 18:38 sunset 07:19 moonrise 21:03 moonset	<u>Apr 7</u> 9% moon 18:39 sunset 07:59 moonrise 22:12 moonset
<u>Apr 10</u> 36% moon sunset moonrise 10:29 moonset 00:24	<u>Apr 11</u> 48% moon sunset moonrise 11:31 moonset 01:23	<u>Apr 12</u> 59% moon sunset moonrise 12:36 moonset 02:15	<u>Apr 13</u> 70% moon sunset moonrise 13:42 moonset 03:01	<u>Apr 14</u> 79% moon sunset moonrise 14:48 moonset 03:41
<u>Apr 17</u> 98% moon sunset moonrise 17:58 moonset 05:20	<u>Apr 18</u> 100% moon 1 sunset moonrise 18:59 moonset 05:51	<u>Apr 19</u> 99% moon sunset moonrise 19:59 moonset 06:22	<u>Apr 20</u> 97% moon sunset moonrise 20:58 moonset 06:55	<u>Apr 21</u> 93% moon sunset moonrise 21:56 moonset 07:30

Figure 8a. Solar and lunar almanac¹⁰.

8.1) Before First Flight for Each Evaluation Pilot

8.1.1) In-briefing

Each evaluation pilot will receive an in-brief before the first flight. The in-brief will include:

- a.) Purpose of test
- b.) Waivers to sign
- c.) Documentation of rotorcraft experience, NVG experience.
- d.) Documentation of corrective eye wear (diopter including astigmatism).
- e.) Training on the subjective ratings and questionnaires
- f.) Format for the daily report
- g.) Test schedule

8.1.2) USAF Tri-Bar Resolution Test

Before the first night flight of each evaluation pilot, the pilot will drive a vehicle to the test site and adjust the goggles for best focus of an Air Force Tri-Bar resolution chart, set at 50 foot distance. The pilot will record the smallest tri-bar pattern that can still be distinguished as three separate bars. This test will be repeated for each tube of both goggles. Afterwards, the goggles will be refocused by the evaluation pilot as desired for flight (close to infinity). Since the focus of the eyepieces of the PNVGs cannot be adjusted by the operator, the evaluation pilot will wear the same corrective eyewear (glasses or contact lenses) as during flight while performing the tri-bar resolution tests. This test will not be done through the aircraft canopy, which may also reduce contrast and resolution.

8.2) Before Each Flight

8.2.1) Preflight Briefing

The research pilot (aft cockpit) will receive a mission briefing in accordance with AFDD Memo 95-1. The test team will conduct a preflight test briefing before each data collection flight. As a minimum, the flight crew, the Test Director, and a representative from the ground support personnel in the test area will attend the briefing. The research pilot and test director will use section 11.2 “Verify Before Each Flight” of this test plan as a checklist during the test briefing.

8.2.2) Preparation of Ground Equipment

Before each data flight the portable ground station will be set up and proper operation will be verified before aircraft engine start. The test director will verify his “before flight” checklist of items that must be set up or configured on the ground before aircraft engine start.

If the ramp area is used, the flight test director will obtain permission from the tower to place traffic cones on the ramp. The traffic cones on the grass field should be in place for the duration of the test.

8.2.3) Aircraft Preflight

A preflight by the research pilot is required before each flight.

8.3) Flight

8.3.1) Aircraft Configuration

This section details the configuration of the aircraft during testing in the designated test area only. This configuration does not necessarily apply outside the test area, or while data are not being recorded.

The Stability Augmentation System will be on.

The force trim will be on or off, at the pilot's discretion.

The anticollision lights and position lights may be turned off if ground reflections are distracting to the pilot. The search light (with the NVG filter) is off and is positioned in the stowed position. The landing light (without the NVG filter) is off.

Both cockpits will be operating with NVG Lighting (green) on, and Normal Lighting (red) off.

The attitude, altitude, and airspeed instruments are covered in the front cockpit to force the pilot to use the image intensified imagery to meet performance targets, instead of using instruments.

The experimental data system will be installed and operating.

The Pilot Night Vision Sensor (PNVS) System is off.

8.3.2) DGPS Position Validation

At the beginning of each data flight, the pilots will land the aircraft on the DGPS calibration point, which is located in the center of the pirouette circle, with the aircraft heading at magnetic north.

8.3.3) NVG adjustment

At the beginning of each night flight, the pilot will adjust the goggles for proper fit. The first (major) adjustment was already completed during the Air Force Tri-Bar resolution test (on ground, before the first night flight). However fine adjustment may be required and is done in the cockpit, while the aircraft is on the ground at the DGPS calibration point.

8.3.4) Head Tracker Calibration

After the NVG adjustment, and while the aircraft is still at the DGPS calibration point, a data record of approx. 10 seconds will be taken while the evaluation pilot holds his/her head level with the horizon, and aligned with the longitudinal axis of the aircraft.

8.3.5) Data Collection

The test matrix is implemented as described in section 4 of this plan. All constraints described in section 11 of this test plan are adhered to.

The Test Director records the configuration for each data run. Configuration will include the data record file name, and the value of each dimension of the test matrix (task, visual condition, pilot, repetition number). The configuration record also includes the serial numbers of the night vision devices used. The test director will archive the configuration data with the raw data.

8.3.6) Pilot Oral Comments

The Test Director will record subjective ratings of the pilots, as well as any other pilot comments during the flight test. The flight crew will transmit all comments to the ground over the VHF radio on frequency 123.225 MHz.

8.4) Post Flight

8.4.1) Post Flight Briefing

A post flight briefing will occur after each data collection flight. Both pilots will attend the briefing along with the test director.

8.4.2) Pilot Written Comments

Each evaluation pilot will complete a daily report following each data collection flight using the standard daily report format provided by the FPO.

8.4.3) Verification of data collection

Data collection files will be examined after each flight to ensure that data has been collected for each measured parameter. This check verifies that the data acquisition system is still functioning. Post-flight analysis does not have to occur before the next flight, only verification that data from the last flight has been collected and stored.

8.5) After Last Flight of Each Evaluation Pilot

8.5.1) Out Briefing

There is no formal out briefing. However, each evaluation pilot may comment on the test procedures for the purpose of improving the test methods for future tests.

9) Post Test

Items listed in this section are performed after all the data flights are completed.

9.1) Photo and Video Documentation

Before the visual markings are removed, the test team will document all maneuvers from an aerial platform. This video will be shot during daylight conditions only.

9.2) Data Analysis

All data will be processed by the Flight Control and Cockpit Integration Branch, for inclusion into the test reports.

9.3) Archiving of Raw and Processed Data

All raw data and processed data will be archived at Ames Research Center as aircraft configuration control documents, by the Flight Control and Cockpit Integration Branch.

9.4) Test Reports

The Flight Control and Cockpit Integration Branch has the responsibility to document the test methods and test results in written reports and oral briefings.

10) Risk Identification, Mitigation, and Assessment

A safe operation will be given the highest priority throughout the test program. This section addresses the safety of this test.

10.1) Overall Risk Assessment

Using the Army standard risk assessment chart shown in figure 10.1a, the overall assessment of risk for this test is Low. This combination corresponds to a “Priority 2” on the NASA risk assessment chart.

HAZARD SEVERITY		HAZARD PROBABILITY				
		FREQUENT Likely to Occur Frequently During The Test	PROBABLE Will Occur Several Times During the Test	OCCASIONAL Likely to Occur Sometime During the Test	REMOTE Unlikely but Possible to Occur During the Test	IMPROBABLE So Unlikely It Is Assumed Occurrence May Not Be Experienced
		A	B	C	D	E
CATASTROPHIC Death or System Loss	I	High	High	High	High	Medium
CRITICAL Severe Injury or Major System Damage	II	High	High	High	Medium	Low
MARGINAL Minor Injury or Minor System Damage	III	High	Medium	Medium	Low	Low
NEGLIGIBLE Less Than Minor Injury or System Damage	IV	Medium	Medium	Low	Low	Low

Figure 10.1a. US Army risk assessment chart.

10.2) Identification, Mitigation, and Assessment of Each Risk

In this section each risk is identified, along with the action to reduce the risk. The possibility of an accident is considered improbable. However, in the event of an accident, the maneuver area is immediately accessible by the crash/rescue/fire team, which will be on duty during all flights.

10.2.1) Collision with Obstacles

Hazard Assessment: III-E

There are no obstacles of significant size in the test area; therefore the hazard assessment is III-E. There are obstacles outside the test area. The location of the closest obstacles outside the test area is shown in figure 10.2.1a.

Photographs of these obstacles are shown in figures 10.2.1b through 10.2.1g. The test area will be surveyed (i.e. inspected) on the ground by each pilot prior to the first flight of that pilot in the test area.

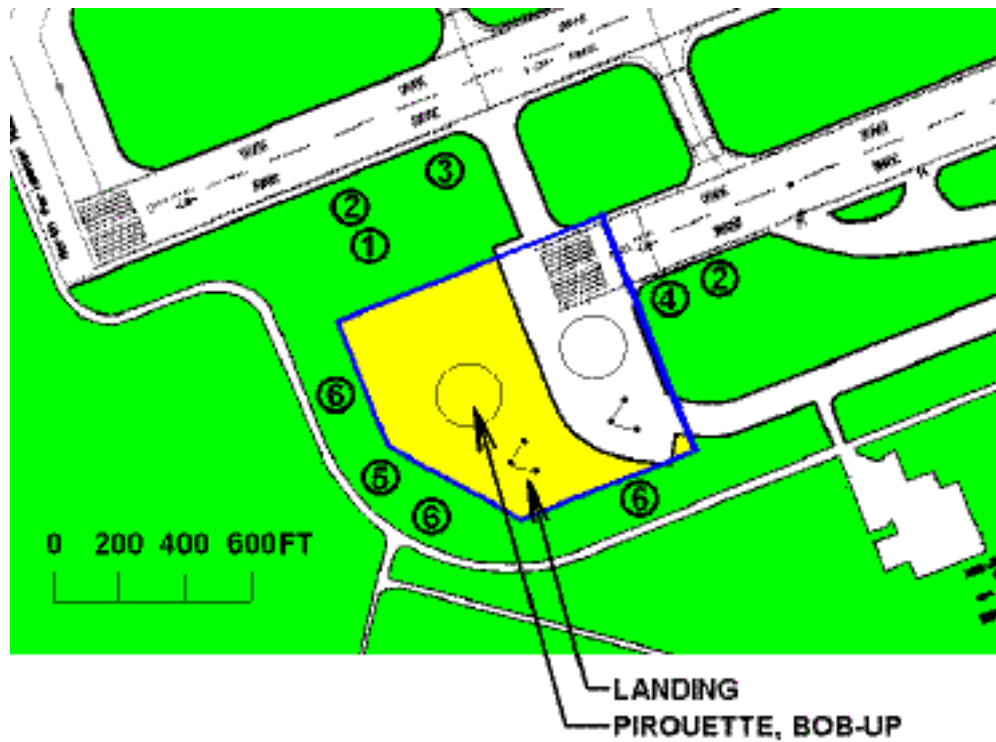


Figure 10.2.1a. Location of Obstructions. Grass area is preferred, concrete area will be used if the grass area is too soft from rain.



Figure 10.2.1b. Obstruction #1, wind sock.



Figure 10.2.1c. Obstruction #2, well marker pole (2 locations).



Figure 10.2.1d. Obstruction #3, 1000 ft marker. Windsock shown in background.



Figure 10.2.1e. Obstruction #4, sewer cover and marker pole.



Figure 10.2.1f. Obstruction #5, laser tracker.



Figure 10.2.1g. Obstruction #6, fence.

The maneuver area is controlled by Moffett Tower. The tower will control the incursion of any vehicles and notify the crew of the placement of any new obstacles.

Traffic cones will be used as visual markers. These cones have been used safely for many years as visual markers in helicopter maneuver areas by NASA-Ames Research Center. The cones have enough weight on their own (without chains) to prevent the cones from becoming airborne and becoming a hazard to the aircraft rotors. Chain weights will be used to keep the cones from blowing over, and reducing the height of the visual cue. The height of the cone in the center of the pirouette circle will be reduced so that it cannot touch the bottom of the fuselage even if the aircraft has landed over the cone.

No visual marker panels will be placed in the maneuver area for this test to eliminate the possibility of the panel becoming airborne. Furthermore, no ropes or tape will be used in this test to eliminate the possibility that the rope or tape will become airborne and get entangled with the aircraft.

10.2.2) Collision with Ground

Hazard Assessment: III-E

The maneuvers are not considered to be disorientating. US Army standard pilot training and qualifications apply to insure that the aircraft is controlled by a capable research pilot. The night vision devices used are considered to be the same or better quality than devices currently used by the Army for rotorcraft operations. Furthermore, the research pilot (aft cockpit) will monitor the aircraft altitude with the radar altimeter indicator.

10.2.3) Operation Inside the “Avoid” Region of the Height Velocity Chart Hazard Assessment: II-E

The AH-1S Height/Velocity Chart⁸ is shown in figure 10.2.3a. The aircraft is a single engine aircraft, and therefore can be damaged if the engine fails while in the “Avoid” region of the Height/Velocity Chart. The only time the aircraft will be operating in the “avoid” region of the AH-1S Height/Velocity Chart during the three maneuvers is during the bob-up/turn/bobdown maneuver. Any hover above 20 ft is within the “avoid” region of the chart. However, overall time spent in this portion of the curve is expected to be less than 1 minute for each repetition of the bobup/turn/bobdown maneuver. Note that the bob-up maneuver is nearly identical to Task 1036 “Perform hover OGE check”, in the Aircrew Training Manual Attack Helicopter, AH-1⁹. In this maneuver, the pilot does a hover OGE check at 50 ft altitude.

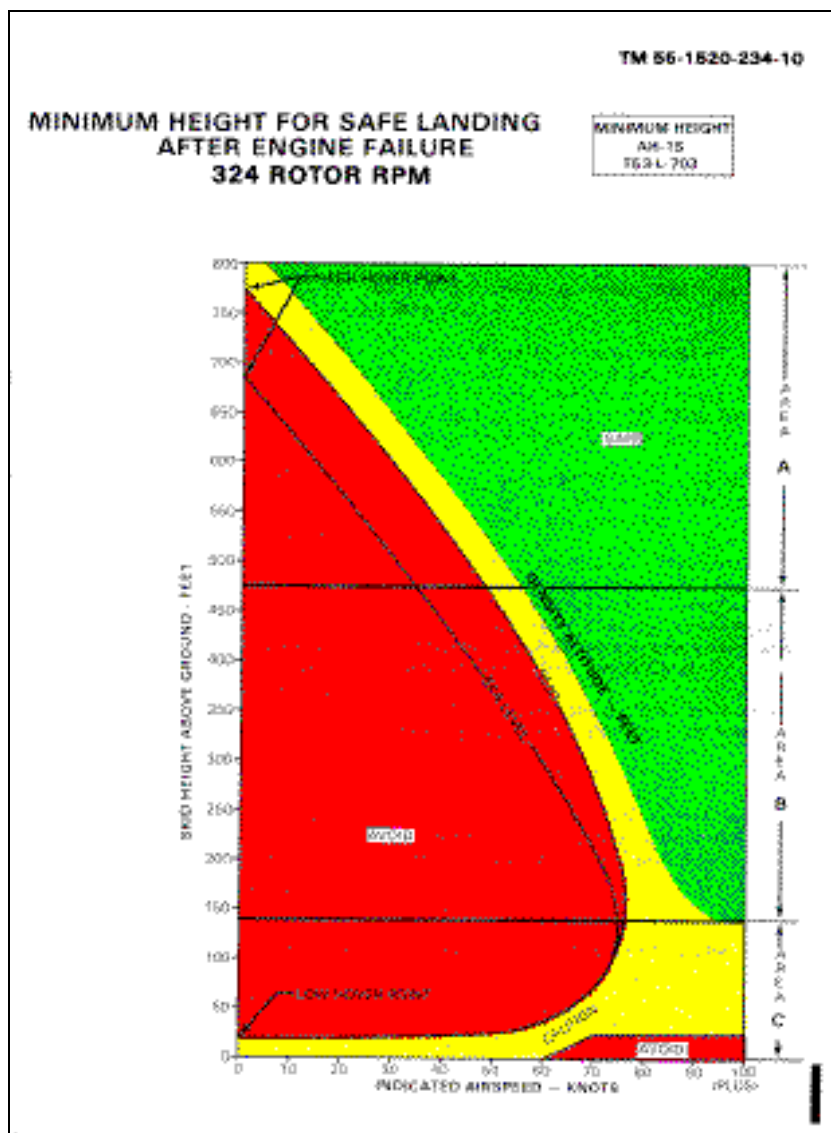


Figure 10.2.3a. Height-Velocity Chart for the AH-1S.

10.2.4) Failure of the Night Vision Device

Hazard Assessment: IV-D

Both night vision devices can have single point failures which disable all tubes. If any of the tubes fail for the pilot at the controls, then that pilot will initiate one of several actions, depending on the current situation:

- a.) Transfer controls to the other pilot, land.
- b.) Turn on search light, land.
- c.) Land.

The test will not continue until all tubes for both pilots work properly.

10.2.5) Bright Lights in the Maneuver Area

Hazard Assessment: III-D

Bright lights near the test area will degrade the quality of the image seen through both types of night vision goggles used in this test. The degraded image can result in loss of situational awareness and impact with obstacles or the ground.

The maneuver area is controlled by Moffett Tower personnel. Therefore, no unannounced incursions of vehicles with bright lights should occur in the maneuver area. The proximity of the runways could result in an aircraft landing with bright landing lights near the test area. The pilot-in-command will request the control tower operator to provide early notification concerning any landing aircraft to the active runways. This control measure will prevent the flight crew from having an unexpected NVG degradation near the ground. The pilot-in-command can best evaluate the impact of the landing aircraft and will determine if the test may proceed or wait until the aircraft lands.

As stated explicitly in section 11, the research pilot (aft cockpit) will determine the impact of vehicle lights on N. Perimeter Road, Zook Road, and Lindberg Ave. before conducting NVG operations. The research pilot will determine if vehicle lights degrade the goggles to the point of being a nuisance or a hazard. These roads will be closed if vehicle lights are determined to be a hazard. Also, the research pilot will determine which obstruction lights, runways lights, and taxiway lights degrade the goggles to the point of being a hazard. If any lights are determined to be a hazard, the test director will have these lights turned off during NVG operations or determine an alternative measure to dim the adverse lighting.

10.2.6) Head Tracker Cord Attachment

Hazard Assessment: IV-E

A small electromagnetic sensor must be attached to the pilot's helmet as part of the head tracking system. This sensor is attached directly to a cord, and there is no disconnect. The sensor will therefore be attached to the helmet with either velcro or tape, such that the sensor will detach from the helmet

with no more than 5 lbs of pull. A pull test will be performed to verify that the sensor detaches from the helmet will less than 5 lbs of pull.

10.2.7) Failure of Experimental Systems

Hazard Assessment: III-E

All mechanical and electrical installations of experimental systems were approved by the local airworthiness review procedures at the time of the installations.

The experimental electrical systems are isolated from the standard AH-1S electrical systems with circuit breakers. Furthermore, the circuit breakers will prevent the experimental systems from overloading the aircraft's electrical busses.

Commercial off-the-shelf components will be used in the data acquisition system. It is improbable, but possible, that components may begin to burn which may also give off toxic fumes. The pilot has a switch in the cockpit which will turn off electrical power to all experimental systems. Furthermore, the maneuvers are all at low altitudes on the airfield. Therefore the aircraft can be set down on the ground quickly. All flight tests will be performed on the airfield, with the fire crew on duty.

A mechanical failure of cockpit mounted experimental components can cause impact with the pilot during a crash. Cockpit mounted components will be analyzed or tested for 15g crash loads in all three axis. A mechanical failure of non-cockpit mounted components can cause control rod damage internally, or become an object than can collide with the main/tail rotors externally. All non-cockpit mounted experimental components will be analyzed or tested for 8 g crash loads in all three axis.

10.2.8) Loose Objects in the Cockpit

Hazard Assessment: III-D

The evaluation pilot will be flying at night with one goggle on the helmet, and one goggle stored. The stored goggle can become a loose object in the cockpit, possibly interfering with the flight controls. Therefore a storage device will be fabricated and installed in the front cockpit to hold the goggles. The inside of the mount will be made of a soft fabric to prevent the lenses from getting scratched.

10.2.9) Standing Water and Mud in Test Area

Hazard Assessment: IV-E

The grass areas in the test area can have standing water and mud after a heavy rain. The research pilot (aft cockpit) will examine the test area for standing water, and sufficient dryness for landing if it has rained since the last flight. If the grass areas are unsuitable for hover and landing, then the test maneuvers will be moved to the north end of the west parallel taxiway. As shown in

figure 10.2.9a, the concrete on the north end of the west parallel taxiway remains above water even after very heavy rains.

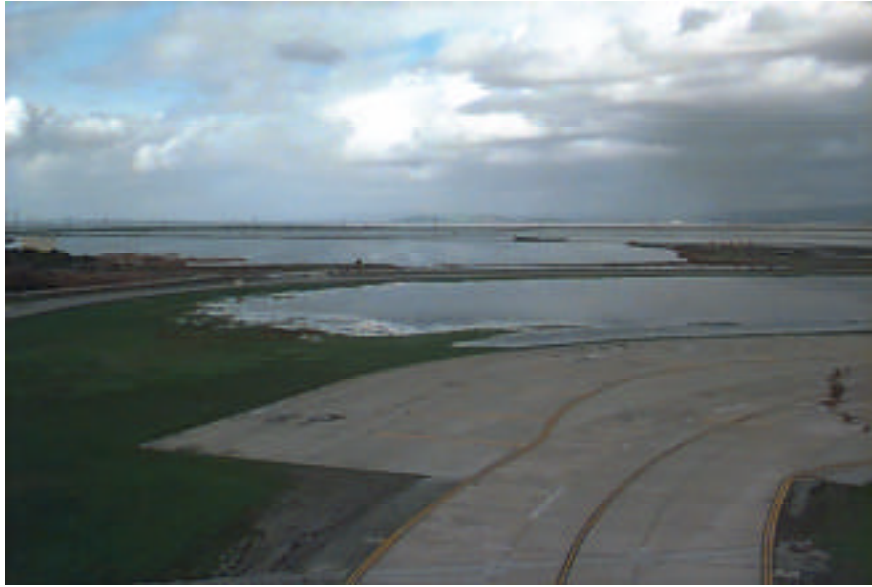


Figure 10.2.9a. Test area north of the west parallel under water during the 1998 flood. Note that the west parallel taxiway is still above water.

11) Safety Checklist

11.1) Verify Once Before Tests Begin

This section is used to explicitly state the safety constraints for the test. The items in this section must be checked for compliance before the start of the first test flight, and do not need to be checked again.

11.1.1) Safety Review

The Safety-of-Flight Review Board (SOFRB) will review this test plan, and the aircraft modifications, in accordance with Flight Project Office (FPO) Procedures. If there are any changes to the test plan or aircraft modifications, the FPO will determine if the SOFRB must reconvene.

11.1.2) PNVG-2 Operation Training

The Air Force will provide a training session to each research pilot, and also the flight test director on the attachment, adjustment, operation, and detachment of the PNVG-2 goggles. The research pilots or the test director will then train each evaluation pilot.

11.1.3) Evaluation Pilot Head Tracker Cord Detachment

A pull test will be performed to verify that the head tracker cord and sensor pull away from the evaluation pilot's helmet with less than 5 pounds of force.

11.1.4) Cockpit GPS Navigation Inoperative

The cockpit GPS navigation system will be disconnected for this test. The aircraft logbook will be marked accordingly. Note that the ADF system has been removed previously. Therefore the only navigation systems for the aircraft is the horizontal situation indicator, driven by the aircraft's heading gyro, and the aircraft's standby compass.

11.1.5) Briefing to Airfield Management and Base Operations

The test director and the Chief, FPO will brief the Airfield Management Office and Base Operations personnel on the conduct of all testing associated with the PNVG test. The test director will include the following items in the briefing: the issuance of a NOTAM to close the west parallel taxiway north of taxiway bravo and 32L during test operations; the removal and installation of visual markers for the test; the removal/dimming of airfield lighting that is deemed as a hazard in the test area, the working hours of contractor fuel and crash/rescue personnel to support the test, ground communication between the ground station and Tower/aircraft, early notification to the flight crew of approaching aircraft and vehicles, and the method for notifying Base Operations and Tower personnel concerning the initiation and completion of daily flight activities.

11.1.6) Verification of No Lighting Hazards

Before the tests begin, the research pilot will verify that obstruction lights, runway lights, and taxiway lights do not degrade the image of either the AN/AVS-9 goggles, or the PNVG-2 goggles to the point that the degraded image is considered a hazard. The degraded image must be no worse than a nuisance, as opposed to a hazard.

Before the tests begin, a vehicle will be driven onto Zook Road at night, and parked with the high-beams shining directly into the test area. The research pilot in the test area will verify that vehicle's lights will not degrade the image of either the AN/AVS-9 goggles, or the PNVG-2 goggles to the point that the degraded image is considered a hazard. With Zook Road, North Perimeter Road, or Lindberg Avenue open, the degraded image must be no worse than a nuisance, as opposed to a hazard.

If the vehicle lights on Zook Road, North Perimeter Road, or Lindberg Avenue have sufficient brightness to degrade the NVG image to the point of creating a hazard, then these roads must be closed while the aircraft is operating in the test area at night.

11.1.7) Team Briefing

The team will review the AFDD Pre-accident Plan before the tests begin.

11.1.8) Submitting Forms for Human Subject Use

NASA forms for the use of human-subjects will be filled out if required.

11.1.9) Aircraft Weight and Balance

The aircraft weight and balance will be recomputed or measured for the installation of the data acquisition system. The weight and balance will then be checked to make sure that they are within the aircraft limits.

11.1.10) Maintenance and inspection Requirements of the Goggles

The AVS-9 goggles must be maintained according to USAF procedures for the AVS-9. Note that the AVS-9 goggles are in the Air Force inventory, but not the Army inventory. The two goggles are nearly identical, with the AVS-9 having better tubes, and superior adjustment mechanisms.

The PNVG-2 is an experimental device. Therefore, there are no established maintenance and inspection requirements. The PNVG-2 device will be inspected for proper function by the Air Force before being hand-carried to Ames.

11.1.11) Electro-Magnetic Compatibility Check

An electro-magnetic compatibility check will be performed on the ground after installation of the research systems to verify that the aircraft systems are not affected by the research systems. After successfully demonstrating that

aircraft systems are not affected by the research systems while on the ground, an in-flight electro-magnetic compatibility check will be performed.

11.1.12) NVG Storage in Cockpit

A storage device will be fabricated and installed in the front cockpit to hold both types of goggles securely.

11.2) Verify Before Each Flight

This section is used to explicitly state the safety constraints for the test. The items in this section must be checked for compliance during each preflight briefing.

11.2.1) Research Pilot Qualifications and Training

The research pilot in the aft cockpit will be NVG qualified and current in the NAH-1S. The research pilot in the aft cockpit will have a minimum of 15 hours of AN/AVS-6, 9 flight time in the last 30 days prior to conducting the test. Additionally, if the evaluation pilot is not qualified and NVG current in the NAH-1S, then the research pilot must be a current NVG instructor pilot for the NAH-1S.

11.2.2) Evaluation Pilot Qualifications and Training

The evaluation pilots will fly the aircraft from the front cockpit. All pilots will be shown all obstacles in the test area, receive and airfield orientation brief, and conduct a cockpit familiarization of the front seat prior to conducting flight operations. Flight crews will also undergo blind cockpit drills and day and night egress with NVGs installed before conducting NVG operations. The research pilot or the test director will provide a training session for each evaluation pilot on the attachment, adjustment, operation, and detachment of the PNVG-2 goggles.

The test team will select evaluation pilots with qualifications as listed below in priority order:

A.) Test Pilot, NVG current in the AH-1S

No additional training is required outside that listed in the test matrix in section 4 of this test plan.

B.) Not a test pilot, NVG current in the AH-1S

No additional training is required outside that listed in the test matrix in section 4 of this test plan. However, training on the ground is required in the use of the subjective measures (ratings).

C.) Test Pilot, Not NVG qualified or current in the AH-1S but a qualified AH-1S pilot

No additional daylight training is required outside of the test matrix. An additional 1 hr of night training with AVS-6,9 goggles is required in addition to that shown in the test matrix.

In this case, the Research Pilot in the aft cockpit must be a current NVG instructor pilot for the AH-1S.

AMC and the FPO must approve any pilot that is not NVG qualified in the AH-1 prior to the conduct of the test.

11.2.3) Ground Crew Requirements

Raytheon will provide a flight mechanic, technical inspector, and a manager when NVG operations are conducted. Raytheon personnel will have access to all tools and supplies to effect repairs without impacting the flight schedule to the greatest extent possible. Raytheon will advise the Government Flight Representative (GFR) that all personnel are prepared to conduct night ground operations in accordance with approved contractor procedures. Raytheon will coordinate for fuel availability during night operations as required by the Test Director. A representative for the ground crew will attend all test briefings and post flight briefings.

11.2.4) Aircrew Coordination

For all flights, the research pilot in the aft cockpit will be the pilot-in-command. The research pilot will initiate the transfer of aircraft controls from the evaluation pilot (forward cockpit) any time the research pilot feels that the evaluation pilot is either not in control of the aircraft, or the evaluation pilot is not aware of a dangerous situation.

The evaluation pilot will initiate the transfer of aircraft controls to the research pilot any time the evaluation pilot feels that he/she is unable to control the aircraft.

The transfer of controls will be a positive transfer of controls, and will be briefed by the research pilot to the evaluation pilot.

11.2.5) Briefings

The research pilot (aft cockpit) will receive a mission briefing in accordance with AFDD Memo 95-1. This briefing requires a low risk briefer.

A test briefing will occur before each data collection flight. As a minimum, the flight crew, the test director, and a representative of the ground support crew must attend this briefing.

The research pilot will conduct a crew brief in accordance with the aircraft ATM. The crew briefing will include at a minimum:

- a.) Aircrew coordination including the positive transfer of the aircraft controls.
- b.) Emergency procedures for an engine failure above 20 ft altitude.
- c.) Procedures for the loss of the intensified image (goggle failure).
- d.) Detachment of the night vision device from the helmet before crash.
- e.) Use of the shoulder harness lock to reduce injury due to the goggles, if goggles are not removed before crash.

11.2.6) Other Pilot And Non-Pilot Evaluation of the PNVGs

Demonstration flights for non-AH-1S qualified pilots and non-pilot observers may occur from the front seat of the NAH-1S both day and night. Night demonstration flights require the approval of the FPO and AMC for both pilots and non-pilots. These pilots and non-pilot observers are test pilots, PNVG engineers, and/or human factors researchers. Non-pilot observers will not manipulate the flight controls during any evaluation flight.

11.2.7) Displays used by the Research Pilot

The research pilot in the aft cockpit will use AV/AVS-6 or AV/AVS-9 night vision goggles. The research pilot will not use experimental displays.

11.2.8) Covering the Evaluation Pilot's Indicators

Only the evaluation pilot's altitude, attitude, and heading indicators will be covered.

11.2.9) Aircraft Maneuver Constraints

All test aircraft will be flown within the published flight envelope of the aircraft. Time spent in the "avoid" region of the AH-1 Height Velocity Chart will be minimized.

11.2.10) Wind Constraints

For all data collection runs, the winds must be below 10 knots as reported by the Moffett Tower.

11.2.11) Weather Constraints

All day and night flights will be under Visual Meteorological Conditions (VMC).

No night flying will be allowed with precipitation. Day training flights will be allowed with precipitation. Day data collection flights will not be flown with precipitation because water on the canopy affects the image seen by the pilot.

11.2.12) Minimum/Maximum Fuel Constraints

The NAH-1S will be flown at all times such that there will be enough fuel to return to the landing/refueling site with at least 300 lbs of fuel remaining.

11.2.13) Crash/Rescue Requirements

A crash/rescue crew must be on duty at the airfield where the maneuvers are flown – i.e. Moffett Field. The control tower operator is responsible for ensuring that the crash/rescue team is on duty, and that the communication link is functioning. The control tower operator is responsible for communication with the crash/rescue team.

11.2.14) Control Tower Requirements

The control tower must be manned and operational during all flights. The research pilot will request that the tower provide early notification of expected aircraft and vehicle traffic near the test area. The test director will notify Moffett Tower at least 2 hours prior to the start of flight operations and when flight operations are concluded.

11.2.15) Required Radio Contacts

The aircraft must be in radio contact with both the tower and the portable ground station. The primary radio for communication with the tower will be the UHF radio. The research pilot (aft cockpit) is responsible for obtaining permission from the control tower to operate in the test area.

The primary radio for communication with the portable ground station will be the VHF radio on frequency 123.225 MHz. There will be no back-up UHF radio in the portable ground station. If the aircrew experiences loss of communication with either the tower or the portable ground station, the test will terminate.

The Test Director in the portable ground station must also have VHF or cell phone communication with the tower, since the tower operator will not be able to see the aircraft at night. Furthermore, the tower operator must have communication with the crash/rescue team.

11.2.16) Pilot Survey of the Test Area

Each pilot will survey the test area for obstructions before the first flight of that pilot. Furthermore, the research pilot will survey the grass fields of the test area after each rain to insure that there is sufficient dryness for landing.

11.2.17) Ambient Lighting Constraints

Zero to 100% cloud cover is allowed for this test. There are no daytime restrictions on ambient lighting. There are no nighttime restrictions on ambient lighting.

The test director is responsible for turning off or covering all lights that have been previously identified as a hazard by the research pilot. The test director is responsible for closing roads adjacent to the test site if determined necessary by the research pilot.

After each night flight, the test director is responsible for turning on all lights that were turned off or covered for this test. The test director is responsible for opening any roads that were closed for the test.

Neither set of NVGs will be operated during the day in order to prevent damage to the goggles, unless in a dark room.

11.2.18) Operation of the Laser Tracker

The laser tracker will not operate with the aircraft or the ground crew in the test area.

11.2.19) Visual Markers

The only visual markers will be traffic cones, paint, or chalk. Ropes, tape, and panels (such as plywood) will not be used. In addition, the height of the cone in the center of the pirouette will be shorter than the distance between the bottom of the skids, and the bottom of the fuselage to prevent the cone from touching the bottom of the fuselage.

11.2.20) Release Forms

Legal and medical release forms will be completed by each evaluation pilot as required by NASA.

11.2.21) Crew Rest

The Army Regulation 95-1 for crew rest will be adhered to¹⁰. This regulation covers not only single day maximum flight hours, but also multiple day maximums.

11.2.22) Chase Aircraft

A chase aircraft will not be used for this test.

12) References

- (1) Durnford, S., Crowely, J., Rosando, N.R., Harper, J., DeRoche, S., "Spacial Disorientation: A Survey of US Army Helicopter Accidents 1987-1992", US Army Aeromedical Research Laboratory, USAARL Report No. 95-25, June 1995.
- (2) Szoboszlay, Z., Edwards, K., Haworth, L., Pratty, A., White, J., Halmos, Z., "Predicting Usable Field-of-View Limits for Future Rotorcraft Helmet Mounted Displays", Innovation in Rotorcraft Technology, Royal Aeronautical Society, 1997.
- (3) Haworth, L., Szoboszlay, Z., Kasper, E., DeMaio, J., Halmos, Z., "In-Flight Simulation of Visionic Field-of-View Restrictions on Rotorcraft Pilot's Workload, Performance, and Visual Cueing", American Helicopter Society 52nd Annual Forum, 1996.
- (4) "Display of Aircraft State Information for Ambient Vision Processing Using Helmet Mounted Displays," Robert Hennessy, Thomas Sharkey, Monterey Technologies Inc., USAATCOM TR 97-D-S, 1997.
- (5) "Overcomming the Field of View: Resolution Invariant In Helmet Mounted Displays," James Melzer, Helmet- and Head- Mounted Displays III, SPIE, 13-14 April 1998.
- (6) "Design, development, fabrication, and safety-of-flight testing of a panoramic night vision goggle," Timothy Jackson, Jeffrey Craig, SPIE Vol. 3689, Helmet- and Head-Mounted Displays IV, 5-6 April 1999.
- (7) "Assessment Methodology for Integrated Helmet and Display Systems in Rotary-wing Aircraft," Clarence Rash, Ben Mozo, William McLean, et al, US Army Aeromedical Research Laboratory, USAARL ReportNo. 96-1, June 1996.
- (8) "Operators Manual Army Model AH-1S (MOD) Helicopter," TM 55-1520-234-10, Department of the Army, 1976.
- (9) "Aircrew Training Manual Attack Helicopter, AH-1," TC 1-213, Department of the Army, 1992.
- (10) Army Regulation 95-1, page 10, table 3.1.